PATENT ABSTRACTS OF JAPAN

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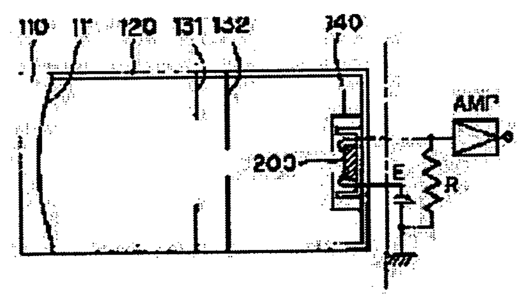
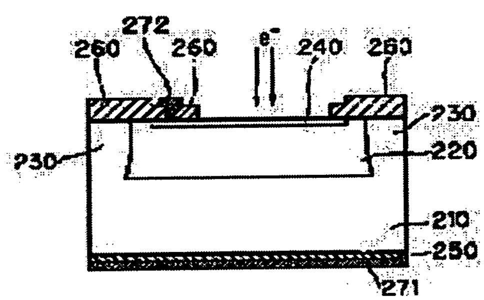
(54) ELECTRON TUBE





(57)Abstract:
PURPOSE: To realize an electron beam radiation type diode having a structor in a thin dead zone which incidental electrons may not intrude into a p-n junction surface, so as to provide an electron tube having improved sensitivity and precision.
CONSTITUTION: Photoelectrons generated by light inciden to a photoelectric surface 111 are accelerated to be incident on an electron beam radiation type diode 200. An inverse bias voltage is applied between an electrode 271 and an electrode 272 of the electron beam radiation type diode 200, and almost all the range of a low concentration impurity layer 220 is formed hollow. The incidental accelerated electrons emit motion energy at a high concentration layer 240 having an electron incidental surface and the hollow low concentration impurity layer 220 to generate electron-positive hole pairs. The high concentration layer 240 having the electron incidental surface is extremely thin, so almost no energy is emitted, but substantially all the energy is emitted in the hollow range. Signal load taken from the electron-positive hole pairs generated by this emission of energy is outputted as signals. from the electrodes 271, 272.

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CLAIMS

[Claim(s)]
[Claim 1] It is the electron tube which enclosed the semi-conductor electron ray detector. Said semi-conductor electron ray detector The silicon substrate which has the 1st conductivity type, and the 1st high concentration impurity layer which has the 1st conductivity type formed in one front face of said silicon substrate, The low concentration impurity layer which has the 2nd conductivity type formed in the front face of another side of said silicon substrate, The isolation layer which has the 1st conductivity type formed in the field which surround said low concentration impurity layer field of the front face of said another side of said silicon substrate, The 2nd high concentration impurity layer which has the 2nd conductivity type formed in the front face of said low concentration impurity layer, The silicon oxide formed in the field including near the periphery of the front face of said isolation layer, and the front face of said 2nd high concentration layer, the 1st electrode formed in the front face of said 1st high concentration impurity layer, and the 2nd electrode formed in the front face of said 2nd high concentration impurity layer -- since -- the electron tube characterized by being constituted and carrying out incidence of the electron from the front face of said 2nd high concentration impurity layer.
[Claim 2] It is the electron tube which enclosed the semi-conductor electron ray detector. Said semi-conductor electron ray detector The silicon substrate which has the 1st conductivity type, and the 1st high concentration impurity layer which has the 1st conductivity type formed in one front face of said silicon substrate, The low concentration impurity layer which has the 2nd conductivity type formed in the front face of another side of said silicon substrate, The isolation layer which has the 1st conductivity type formed in the field which surround said low concentration impurity layer field of the front face of said another side of said silicon substrate, The 2nd high concentration impurity layer which has the 2nd conductivity type formed in the front face of said low concentration impurity layer, The silicon oxide formed in the field including near the periphery of the front face of said isolation layer, and the front face of said 2nd high concentration impurity layer, The 1st electrode formed in the front face of said 1st high concentration impurity layer, and the 2nd electrode formed in the front face of said 2nd high concentration impurity layer, Were formed in the field except the field in which said silicon oxide of the front face of said 2nd high concentration impurity layer was formed, and the field in which said 2nd electrode was formed. The wideband gap layer which consists of a semiconductor material which has a bigger band gap than the band gap which said 2nd high concentration impurity layer has, and has the 2nd conductivity type, and carries out a heterojunction to said 2nd high concentration impurity layer, since -- the electron tube characterized by being constituted and carrying out incidence of the electron from the front face of said wideband gap layer.
[Claim 3] It is the electron tube which enclosed the semi-conductor electron ray detector. Said semi-conductor electron ray detector The silicon substrate which has the 1st conductivity type, and the 1st high concentration impurity layer which has the 1st conductivity type formed in one front face of said silicon substrate, The 2nd high concentration impurity layer which has the 2nd conductivity type formed in the 1st field of the front face of another side of said silicon substrate, The 2nd field surrounding said 1st field of the front face of said another side of said silicon substrate, and the low concentration impurity layer which has the 2nd conductivity type formed in the front face of said 2nd high concentration impurity layer, The isolation layer which has the 1st conductivity type formed in

the field which surround said low concentration impurity layer field of the front face of said another side of said silicon substrate, The 3rd high concentration impurity layer which has the 2nd conductivity type formed in the front face of said low concentration impurity layer, The silicon oxide formed in the field including near the periphery of the front face of said isolation layer, and the front face of said 3rd high concentration layer, the 1st electrode formed in the front face of said 1st high concentration impurity layer, and the 2nd electrode formed in the front face of said 3rd high concentration impurity layer -- since -- the electron tube characterized by being constituted and carrying out incidence of the electron from the front face of said 3rd high concentration impurity layer.

[Claim 4] It is the electron tube which enclosed the semi-conductor electron ray detector. Said semi-conductor electron ray detector The silicon substrate which has the 1st conductivity type, and the 1st high concentration impurity layer which has the 1st conductivity type formed in one front face of said silicon substrate, The 2nd high concentration impurity layer which has the 2nd conductivity type formed in the 1st field of the front face of another side of said silicon substrate, The 2nd field surrounding said 1st field of the front face of said another side of said silicon substrate, and the low concentration impurity layer which has the 2nd conductivity type formed in the front face of said 2nd high concentration impurity layer, The isolation layer which has the 1st conductivity type formed in the field which surround said low concentration impurity layer field of the front face of said another side of said silicon substrate, The 3rd high concentration impurity layer which has the 2nd conductivity type formed in the front face of said low concentration impurity layer, The silicon oxide formed in the field including near the periphery of the front face of said isolation layer, and the front face of said 3rd high concentration impurity layer, The 1st electrode formed in the front face of said 1st high concentration impurity layer, and the 2nd electrode formed in the front face of said 3rd high concentration impurity layer, Were formed in the field except the field in which said silicon oxide of the front face of said 3rd high concentration impurity layer was formed, and the field in which said 2nd electrode was formed. The wideband gap layer which consists of a semiconductor material which has a bigger band gap than the band gap which said 3rd high concentration impurity layer has, and has the 2nd conductivity type, and carries out a heterojunction to said 3rd high concentration impurity layer, since -- the electron tube characterized by being constituted and carrying out incidence of the electron from the front face of said wideband gap layer.

[Translation done.]

* NOTICES *

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Industrial Application] This invention relates to the photoelectric tube which uses electron-beam-irradiation mold diode especially as an anode with respect to the photoelectric tube which detects the light which carried out incidence.
[0002]
[Description of the Prior Art] If an electron carries out incidence to a silicon component, an electron will emit kinetic energy and, finally will stand it still. In a silicon component, one pair of electronic-electron holes generate every energy emitted 3.6eV. Therefore, if the electron emitted from the photoelectric surface where -10kV was impressed carries out incidence to a silicon component, it is possible for about 2800 electronic-electron hole pairs to be generated, and to take out a pair of one side as a signal charge. Therefore, it is theoretically possible to constitute the photodetector which can measure quantitatively the number of photons which is very high sensitivity and carried out incidence as an anode with a configuration called ****** in silicon diode to the electron tube which has the photoelectric surface, and the product development is advanced to it.
[0003] Drawing 5 is the block diagram of the electron-beam-irradiation mold diode as a semi-conductor electronic detector used as an anode with the conventional electron tube adapting the above-mentioned principle. Drawing 5 (a) shows the structure section of this electron-beam-irradiation mold diode, and drawing 5 (b) shows distribution of the field strength in the interior at the time of impressing an electrical potential difference to electrode tubing of this semi-conductor electronic detector. The high resistance n mold silicon substrate 710 in which this electron-beam-irradiation mold diode has resistance of (a) 200-micrometer thickness and 1komega-cm, (b) A substrate 710 and p mold high concentration diffusion layer 720 whose so-called depth which carries out step junction and contains p mold impurity of 5x1019cm-3 is 0.5 micrometers, (c) Silicon oxide 730 formed in the surface field except the incidence field of the electron ray of p mold high concentration diffusion layer 720, and the front face of the side in which p mold high concentration diffusion layer 720 of a substrate 710 was formed, (d) n mold high concentration layer 740 which it is formed [layer] in the front face of the opposite side the side in which p mold high concentration diffusion layer 720 of a substrate 710 was formed, and stops the depletion-layer breadth in the substrate 710 at the time of impression of a reverse bias electrical potential difference, (e) -- the electrode 751 formed in the surface field except the incidence field of the electron ray of p mold high concentration diffusion layer 720, and the electrode 752 formed in the front face of (f) n mold high concentration layer 740 -- since -- it is constituted.
[0004] Here, the reason for not forming silicon oxide in the incidence field of the electron ray of p mold high concentration diffusion layer 720 is because the charge generated as an electronic-electron hole pair produced by the kinetic energy of the incidence electron with which silicon oxide was absorbed in it by becoming a neutral zone cannot be taken out as a signal charge.
[0005] Moreover, the reason for using the silicon member of high resistance (1kohm-cm) as a substrate 710 is for making a junction capacitance small and attaining rapidity while it impresses a reverse bias electrical potential difference and extends a depletion layer. For example, a junction capacitance is set to about 0.5pF, when the reverse bias electrical potential difference of 150V is impressed to the above-mentioned electron-beam-irradiation mold diode and it considers as a

depletion condition about the whole thickness of a substrate 710. Since external load resistance is usually 50ohms, actuation of the nanosecond order demanded as an electronic detector which serves as 25psec(s) and is enclosed with the electron tube is possible for CR time constant. In addition, silicon oxide 730 is formed for control of the dark current.
[0006] Drawing 5 (b) shows the field strength distribution between A-B in drawing 5 (a) at the time of impressing a reverse bias electrical potential difference to the above electron-beam-irradiation mold diode. As illustration, within the depletion layer, the electric field to which a signal charge (electron) is moved have occurred, and signs that it becomes the maximal value in respect of pn junction are shown.
[0007] If light carries out incidence to the photoelectric surface of the electron tube, an electron will be emitted from the photoelectric surface. It is accelerated with the electrical potential difference impressed between the photoelectric surface and the above-mentioned electron-beam-irradiation mold diode which is an anode, and the electron chosen with the gobo carries out incidence of this electron to electron-beam-irradiation mold diode from the electron ray plane of incidence of p mold high concentration diffusion layer 720. The electron which carried out incidence emits kinetic energy in the silicon member which constitutes electron-beam-irradiation mold diode, and generates an electronic-electron hole pair. At this time, the reverse bias electrical potential difference was impressed to electron-beam-irradiation mold diode, and the substrate 710 is depletion-ized. The signal charge generated as an electronic-electron hole pair in the depletion layer is outputted as the signal current.
[0008]
[Problem(s) to be Solved by the Invention] The high concentration impurity layer in which the electron-beam-irradiation mold diode currently used with the conventional electron tube is constituted as mentioned above, and an electron ray carries out incidence has good conductivity. Since the dark current will increase sharply for the so-called surface level if a depletion region results even in an interface with silicon oxide although a depletion region grows up to be also this high concentration impurity layer when a reverse bias electrical potential difference is impressed, this is for preventing this. Therefore, since the depletion region in a high concentration impurity layer is formed only in the very thin field near the pn junction side, almost all the fields of the high concentration impurity layer which is a field from the plane of incidence of an electron ray to a depletion layer serve as a neutral zone. Since a signal charge cannot be effectively taken out from the electronic-electron hole pair generated with this neutral zone and the sensibility and precision of the electron tube as a photodetector are reduced, a high concentration impurity layer is so desirable that it is thin.
[0009] However, as a high concentration impurity layer is made thin, electric-field concentration becomes large and breakdown voltage becomes smaller. Furthermore, breakdown voltage will become extremely small if the degree of the curve of junction to the thickness of a high concentration impurity layer becomes large. That is, in order to have secured impression of the reverse bias electrical potential difference which forms sufficient depletion region for the substrate which has high resistance for high-speed operation, there was a problem that the high concentration impurity layer which has a certain amount of thickness was indispensable, and the fall of the sensibility of the electron tube as a photodetector or precision was not avoided.
[0010] Moreover, since it is accelerated and incidence of the electron generated in the photoelectric surface is carried out to electron-beam-irradiation mold diode, by the time it emits kinetic energy and stands it still, it may pass through a pn junction side. For example, if the electron accelerated by 10keV(s) as mentioned above carries out incidence to silicon, since about several micrometers will invade on an average from plane of incidence, by the thickness of a 0.5-micrometer high concentration impurity layer, it passes through the largest pn junction side of field strength almost certainly (refer to drawing 5 (b)). Many energy levels are made by passage of a high energy electron in the band gap of silicon (S. M.SZE : Physics of Semiconductor Devives, p.49). Although these energy levels caused the dark current, generation of the energy level of a large number in the band gap near [where field strength is big] a pn junction side caused the big dark current, and had the trouble of having a bad influence to the sensibility and precision as the electron tube.
[0011] Furthermore, if an electronic exposure progresses, the fall of the pressure-proofing to a

reverse bias electrical potential difference will be assumed by being ruined. When pressure-proofing fell, a reverse bias electrical potential difference could not be impressed to the forge fire which extends a depletion layer widely to a substrate, but CR time constant became large and there was a trouble that a working speed fell.

[0012] This invention aims at offering the electron tube which improved sensibility and precision by realizing electron-beam-irradiation mold diode of the structure where it is made in view of the above-mentioned situation, and can make a neutral zone thin, and an incidence electron does not trespass even upon a pn junction side.

[0013]

[Means for Solving the Problem] The electron tube of this invention forms the pn junction side of the electron irradiation mold diode which is the semi-conductor electronic detector to enclose in the substrate which contains an impurity in low concentration, and the low concentration impurity layer which is a low concentration impurity layer. While crossing the depletion region produced by impression of a reverse bias electrical potential difference throughout the thickness direction of a substrate and a low concentration impurity layer and forming it, the high concentration impurity layer which has the same conductivity type as the low concentration impurity layer which stops growth of a depletion region is formed in the front face where the pn junction side of a low concentration impurity layer is opposite. Consequently, the thickness of this high concentration impurity layer does not cause pressure-proof, but solution of the trouble of the conventional electron tube is aimed at using what thickness of this high concentration impurity layer can be made thin for.

[0014] The 1st electron tube of this invention is the electron tube which enclosed the semi-conductor electron ray detector. Namely, a semi-conductor electron ray detector (a) The silicon substrate which has the 1st conductivity type, and the 1st high concentration impurity layer which has the 1st conductivity type formed in one front face of the (b) silicon substrate, (c) The low concentration impurity layer which has the 2nd conductivity type formed in the front face of another side of a silicon substrate, (d) The isolation layer which has the 1st conductivity type formed in the field which surround the low concentration impurity layer field of the front face of another side of a silicon substrate, (e) The 2nd high concentration impurity layer which has the 2nd conductivity type formed in the front face of a low concentration impurity layer, (f) Silicon oxide formed in the field including near the periphery of the front face of an isolation layer, and the front face of the 2nd high concentration layer, (g) -- the 1st electrode formed in the front face of the 1st high concentration impurity layer, and (h) -- the 2nd electrode formed in the front face of the 2nd high concentration impurity layer -- since -- it is characterized by carrying out incidence of the electron from the front face in which it is constituted and the silicon oxide of the 2nd high concentration impurity layer is not formed.

[0015] The 2nd electron tube of this invention is the electron tube which enclosed the semi-conductor electron ray detector. A semi-conductor electron ray detector To the field except the field in which said silicon oxide of the front face of the 2nd high concentration impurity layer of the semi-conductor electron ray detector in the 1st electron tube of the above was formed, and the field in which the 2nd electrode was formed It consists of a semiconductor material which has a bigger band gap than the band gap which the 2nd high concentration impurity layer has, the wideband gap layer which carries out a heterojunction to said 2nd high concentration impurity layer is formed, and it is characterized by carrying out incidence of the electron from the front face of a wideband gap layer.

[0016] The 3rd electron tube of this invention is the electron tube which enclosed the semi-conductor electron ray detector, and a semi-conductor electron ray detector is characterized by what the high concentration impurity layer was formed for between the substrates of a semi-conductor electron ray detector and low concentration impurity layers in the 1st electron tube of the above.

[0017] The 4th electron tube of this invention is the electron tube which enclosed the semi-conductor electron ray detector, and a semi-conductor electron ray detector is characterized by what the high concentration impurity layer was formed for between the substrates of a semi-conductor electron ray detector and low concentration impurity layers in the 2nd electron tube of the above.

[0018]

[Function] In the 1st electron tube concerning this invention, the reverse bias electrical potential difference is impressed to electron-beam-irradiation mold diode, and all the fields of the thickness

direction of a low concentration impurity layer are depletion-ized. Therefore, what is not depletion-ized in the invasion field in the electron-beam-irradiation mold diode of an acceleration electron is only a high concentration impurity layer which has the same conductivity type as the low concentration impurity layer formed in the front face of a low concentration impurity layer. Moreover, since an isolation diffusion layer prevents that a pn junction side is exposed to a side face, it inhibits the dark current.

[0019] A photoelectron will be generated if light carries out incidence to the photoelectric surface of this electron tube. It is accelerated and incidence of this photoelectron is carried out to electron-beam-irradiation mold diode. This incidence acceleration electron emits kinetic energy with the high concentration impurity layer which has electronic plane of incidence, the depletion-ized low concentration impurity layer, or a substrate, and generates an electronic-electron hole pair. In this case, since the high concentration impurity layer which has electronic plane of incidence is very thin, emission of energy is hardly made but all energy is emitted substantially in a depletion region. The signal charge taken out from the electronic-electron hole pair generated by emission of this energy is outputted as a signal from an electrode.

[0020] the configuration of the electron-beam-irradiation mold diode in the 1st electron tube above-mentioned in the 2nd electron tube concerning this invention -- in addition, as a result of forming a very thin wide gap layer in the plane of incidence of an acceleration electron and carrying out a heterojunction, a good accumulation condition is discovered to a signal charge. Since near the plane of incidence of an acceleration electron is in the good accumulation condition although an electronic-electron hole pair is generated like the 1st electron tube if the photoelectron generated in connection with light carrying out incidence in this condition in the photoelectric surface of this electron tube is accelerated and incidence is carried out to electron-beam-irradiation mold diode, one side of a signal charge arrives at a pn junction side efficiently, and can reduce the recombination near a front face with another side of a signal charge. In this way, the signal charge collected efficiently is outputted as a signal from an electrode. In addition, a wideband gap layer acts also as a kind of passivation film, and protects electron-beam-irradiation mold diode from contamination of the alkali metal generated at the time of enclosure.

[0021] In the 3rd electron tube concerning this invention, in addition to the configuration of the electron-beam-irradiation mold diode in the 1st above-mentioned electron tube, the high concentration impurity layer which has the same conductivity type as a low concentration impurity layer between a substrate and a low concentration impurity layer is formed, high electric field occur in this high concentration impurity layer at the time of impression of a reverse bias electrical potential difference, and an avalanche multiplication function is discovered. If the photoelectron which light generated in connection with incidence in the photoelectric surface of this electron tube is accelerated and incidence is carried out to electron-beam-irradiation mold diode in this condition, an electronic-electron hole pair will be generated like the 1st electron tube, and one side of a signal charge will advance in the direction of a pn junction side. Just before passing through a pn junction side, avalanche multiplication of one side of this signal charge is carried out. Therefore, the total amount of the signal charge which reaches a substrate becomes what increased compared with the case of the 1st electron tube. In this way, the signal charge which increased is outputted as a signal from an electrode.

[0022] In the 4th electron tube concerning this invention, in addition to the configuration of the electron-beam-irradiation mold diode in the 2nd above-mentioned electron tube, the high concentration impurity layer which has the same conductivity type as a low concentration impurity layer between a substrate and a low concentration impurity layer is formed, high electric field occur in this high concentration impurity layer at the time of impression of a reverse bias electrical potential difference, and an avalanche multiplication function is discovered. Therefore, it has the operation in which the both sides of the improving point in the 2nd electron tube to the 1st electron tube and the improving point in the 3rd electron tube to the 1st electron tube have been improved. Consequently, avalanche multiplication of the signal charge which advances in the direction of a pn junction side efficiently is carried out, and it is outputted as a signal from an electrode.

[0023]

[Example] Hereafter, the example of this invention is explained with reference to an accompanying

drawing. In addition, in explanation of a drawing, the same sign is given to the same element, and the overlapping explanation is omitted.
[0024] (The 1st example) Drawing 1 is the block diagram of the electron tube concerning this example, and drawing 1 (a) shows the configuration of the electron-beam-irradiation mold diode with which drawing 1 (b) was enclosed with the electron tube in the configuration of the whole electron tube. The photoelectric-surface plate 110 which has the photoelectric surface 111 which this electron tube receives light and emits an electron, The 1st grid 131 and the 2nd grid 132 which narrow down the electron which constituted enclosure from a glass bulb 120 and was emitted from the photoelectric surface in enclosure, It is constituted including the shield 140 which restricts the course of the accelerated electron, and the electron-beam-irradiation mold diode (it is also only henceforth called diode) 200 which detects the acceleration electron which carried out incidence and outputs a signal charge. A reverse bias electrical potential difference is impressed to diode 200 through load resistance (R) from DC power supply (E). The voltage signal generated to the both ends of the load resistance (R) produced when the signal charge generated for diode 200 flowed load resistance (R) is inputted into amplifier (AMP). In addition, in the electron tube of this example, the acceleration voltage of a photoelectron is 10kV, therefore the penetration depth to the silicon member of an acceleration electron is several micrometers.
[0025] The silicon substrate 210 of 1mm angle on which diode 200 has the conductivity of a (a) n mold, (**) -- with the high concentration impurity layer (n mold high concentration layer being called henceforth) 250 which has the conductivity of n mold formed in one front face of a silicon substrate 210 The anode layer 220 which has the conductivity of p mold formed in the front face of another side of the (c) silicon substrate 210, The isolation layer 230 which has the conductivity of n mold formed in the field which surround anode layer 220 field of the front face of another side of the (d) silicon substrate 210, (**) -- with the high concentration impurity layer (p mold high concentration layer being called henceforth) 240 which has the conductivity of p mold formed in the front face of the anode layer 220 The silicon oxide 260 formed in the front face of the isolation layer 230, and the field including near the periphery of p mold high concentration layer 240, (Mosquito) the electrode 271 formed in the front face of the (g) n mold high concentration layer 250, and the electrode 272 formed in the front face of the (h) p mold high concentration layer 240 -- since -- it is constituted.
[0026] At this example, a silicon substrate 210 is formed from the silicon of 200-micrometer thickness containing n mold impurity of extent used as 0.01ohms of specific resistance cm, and the anode layer 220 forms in 40-micrometer thickness the silicon containing p mold impurity with which specific resistance becomes about 100ohmcm with epitaxial growth.
[0027] Moreover, after forming p type layer in one front face of n mold silicon substrate 210, the isolation diffusion layer 230 diffuses n mold impurity to the predetermined field of p type layer (a part of silicon substrate included as a result), and is formed in it, and it prevents that a pn junction side is exposed to a side face. Consequently, the dark current is inhibited.
[0028] Moreover, p mold high concentration layer 240 is a layer of 0.1-micrometer thickness which has the high impurity concentration of 5x1019cm-3. this thickness -- although all serve as a neutral zone mostly, the thickness of a neutral zone is reduced compared with the configuration of the conventional electron irradiation mold diode. Since the anode layer 220 intervenes between p mold high concentration layer 240 and a silicon substrate 210, the factor as which the thickness of p mold high concentration layer 240 determines pressure-proofing of a pn junction side does not become, and growth of the depletion region accompanying impression of a reverse bias electrical potential difference is stopped effectively.
[0029] A photoelectron will be generated if light carries out incidence to the photoelectric surface 111 of this electron tube. It is accelerated and incidence of this photoelectron is carried out to the electron-beam-irradiation mold diode 200. between the electrode 271 of the electron-beam-irradiation mold diode 200, and an electrode 272, the reverse bias electrical potential difference of abbreviation 100V impresses -- having -- the anode layer 220 -- the whole region and near the pn junction side of a silicon substrate 210, it is depletion-ized mostly. An incidence acceleration electron emits kinetic energy in p mold high concentration layer 240 which has electronic plane of incidence, and the depletion-ized anode layer 220, and generates an electronic-electron hole pair. In

this case, since p mold high concentration layer 240 which has electronic plane of incidence is very thin, emission of energy is hardly made but all energy is emitted substantially in a depletion region. The signal charge taken out from the electronic-electron hole pair generated by emission of this energy is outputted as a signal from an electrode 271 and an electrode 272.
[0030] By the way, the electron of 10keV emits all kinetic energy in the field to a depth of about several micrometers of a silicon member. namely, the penetration depth of an incidence acceleration electron -- about several micrometers -- it is -- a signal charge -- all are almost generated in the anode layer 220. The rise time of the signal current produced when this signal charge flows resistance (R) is mainly determined as time amount until an electron hole reaches p mold high concentration layer 240 from the generating location of an electronic-electron hole pair, and time amount until an electron arrives at a pn junction side from the generating location of an electronic-electron hole pair in the later one. The generating location of an electronic-electron hole pair is about several micrometers from the plane of incidence of an acceleration electron, and the thickness of the anode layer 220 is 40 micrometers. Considering this, even if it takes into consideration the difference with the mobility of the electron in the anode layer 220, and the mobility of an electron hole, the rise time of the signal current is decided by the electronic transit time. Moreover, although the fall time of the signal current is determined by the time amount to which an electron runs the depletion region in a substrate 210, the depletion region in [the difference of specific resistance with a silicon substrate 210 and the anode layer 220 to] a silicon substrate becomes thin, and becomes small compared with the rise time.
[0031] In the electron tube of this example, the maximum of the transit time of the electron of the anode layer 220 is calculated as follows. In addition, a reverse bias electrical potential difference is 100V as mentioned above.
- maximum electric-field -- of the pn junction section produced by perfect depletion-ization of the reverse bias electrical-potential-difference --60V and the anode layer 220 required for depletion-izing of the anode layer 220 -- electric-field --1x104 V/cm produced by 3x104 V/cm and (100V-60V) =40V -- here -- electronic mobility -- 1800cm2/(V-sec) -- carrying out -- = (maximum of the transit time of the electron of the anode layer 220) -- it has been about 0.1ns. Therefore, actuation of nanosecond order is possible for the electron tube of this example.
[0032] In addition, although the anode layer was formed with the epitaxial grown method in this example, you may form with a diffusion wafer or a lamination wafer.
[0033] A speed of operation is comparable, and when the electron tube which enclosed the diode of a large area further is required, it is good, if the part and depletion layer which became a large area and the junction capacitance increased are extended and a junction capacitance is not changed as a result. Specifically, there are the following approaches.
(1) Or it increases the layer growth by epitaxial growth, while forming a thick anode layer using a diffusion mold wafer or a lamination wafer, increase a reverse bias electrical potential difference and extend a depletion layer greatly.
(2) Lower the high impurity concentration of a silicon substrate and consider as the configuration in which a depletion layer spreads also in a silicon substrate side.
[0034] For example, the reverse bias electrical potential difference in which sets thickness of an anode layer to 80 micrometers, and an anode layer carries out all depletion is impressed using a diffusion wafer. Thereby, a plane-of-incidence product is expandable to 1.5mm angle from 1mm angle. In this case, as for the transit time of the signal electron which determines the rise time and the fall time of the signal current, only the part to which the depletion layer became thick becomes long. However, since this transit time is in inverse proportion to the added electric field, twice, then a working speed are [the reverse bias electrical potential difference to impress] securable.
[0035] (The 2nd example) Drawing 2 is the block diagram of the electron tube concerning this example, and drawing 2 (a) shows the configuration of the electron-beam-irradiation mold diode with which drawing 2 (b) was enclosed with the electron tube in the configuration of the whole electron tube. It is only that the electron-beam-irradiation mold diodes to enclose differ compared with the electron tube of the 1st example, and this electron tube is similarly constituted except it.
[0036] In addition to the same configuration as the electron-beam-irradiation mold diode of the 1st example, the electron-beam-irradiation mold diode 300 enclosed with the electron tube of this

example forms in acceleration electronic plane of incidence the wideband gap layer 380 which has the conductivity of p mold by using as a base material the ingredient matter which has a big band gap, and consists of band gaps of silicon. Namely, this electron-beam-irradiation mold diode 300 The silicon substrate 310 of 1mm angle which has the conductivity of a (a) n mold, and n mold high concentration layer 350 formed in one front face of the (b) silicon substrate 310, The anode layer 320 which has the conductivity of p mold formed in the front face of another side of the (c) silicon substrate 310, The isolation layer 330 which has the conductivity of n mold formed in the field which surround anode layer 320 field of the front face of another side of the (d) silicon substrate 310, p mold high concentration layer 340 formed in the front face of the (e) anode layer 320, The silicon oxide 360 formed in the front face of the isolation layer 330, and the field including near the periphery of p mold high concentration layer 340, (Mosquito) the electrode 372 formed in the front face of the (g) n mold high concentration layer 350, the electrode 371 formed in the front face of the (h) p mold high concentration layer 340, and the wideband gap layer 380 of several nm thickness which has the conductivity of a (i) p mold -- since -- it is constituted.

[0037] With a spatter, PVD, or a CVD system, the wideband gap layer 380 makes the silicon carbide which has the same conductivity type as the high concentration layer 340, a cadmium tellurium, etc. deposit, and is formed. This deposition is comparatively possible at low temperature, and does not need to cause damage on a silicon member. Moreover, since it is a wideband gap, while it is stable and not becoming the source of generation of the dark current to a temperature change, a heterojunction is carried out to p mold high concentration layer 340, and acceleration electronic plane of incidence is made into an accumulation condition. Furthermore, it acts also as a kind of passivation film, and electron-beam-irradiation mold diode is protected from contamination of the alkali metal generated at the time of enclosure. In addition, although the wideband gap layer 380 serves as a neutral zone, since it is very thin, the increment in the neutral zone by the wideband gap layer 380 can be disregarded substantially.

[0038] If light carries out incidence to the photoelectric surface 111 of this electron tube, a photoelectron will be generated and incidence will be carried out to diode 300 like the 1st example. between the electrode 371 of diode 300, and an electrode 372, the reverse bias electrical potential difference of abbreviation 100V impresses -- having -- the anode layer 320 -- the whole region and near the pn junction side of a silicon substrate 310, it is depletion-ized mostly. An incidence acceleration electron emits kinetic energy in p mold high concentration layer 340 which has electronic plane of incidence, and the depletion-ized anode layer 320, and generates an electronic-electron hole pair. In this case, since the wideband gap layer 380 and p mold high concentration layer 340 are thin, emission of energy is hardly made but all energy is emitted substantially in a depletion region. Although the electronic-electron hole pair generated by emission of this energy is generated, since near the plane of incidence of an acceleration electron is in the good accumulation condition, on the other hand, a signal charge comes out, and a certain electron arrives at a pn junction side efficiently. In this way, the signal charge collected efficiently is outputted as a signal from an electrode 271 and an electrode 272.

[0039] Also in the electron tube of this example, an anode layer may be formed with a diffusion wafer or a lamination wafer like the 1st example.

[0040] (The 3rd example) Drawing 3 is the block diagram of the electron tube concerning this example, and drawing 3 (a) shows the configuration of the electron-beam-irradiation mold diode with which drawing 3 (b) was enclosed with the electron tube in the configuration of the whole electron tube. It is only that the electron-beam-irradiation mold diodes to enclose differ compared with the electron tube of the 1st example, and this electron tube is similarly constituted except it.

[0041] In addition to the same configuration as the electron-beam-irradiation mold diode of the 1st example, the electron-beam-irradiation mold diode 400 enclosed with the electron tube of this example forms p mold high concentration layer between a substrate and an anode layer, and is constituted. Namely, this electron-beam-irradiation mold diode 400 The silicon substrate 410 of 1mm angle which has the conductivity of a (a) n mold, and n mold high concentration layer 450 formed in one front face of the (b) silicon substrate 410, p mold high concentration layer 490 formed in the predetermined field of the front face of another side of the (c) silicon substrate 410, The anode layer 420 which has the conductivity of p mold formed in the front face of another side of the (d)

silicon substrate 410, The isolation layer 430 which has the conductivity of n mold formed in the field which surround anode layer 420 field of the front face of another side of the (e) silicon substrate 410, p mold high concentration layer 440 formed in the front face of the anode layer 420, (Mosquito) The silicon oxide 460 formed in the front face of the (g) isolation layer 430, and the field including near the periphery of p mold high concentration layer 440, the electrode 472 formed in the front face of the (h) n mold high concentration layer 450, and the electrode 471 formed in the front face of the (i) p mold high concentration layer 440 -- since -- it is constituted.

[0042] p mold high concentration layer 490 is formed by the embedding diffusion method or the epitaxial grown method. When based on an epitaxial grown method, double epitaxial growth is carried out. At the time of impression of a reverse bias electrical potential difference, high electric field occur in p mold high concentration layer 490, and an avalanche multiplication function is discovered.

[0043] If light carries out incidence to the photoelectric surface 111 of this electron tube, a photoelectron will be generated and incidence will be carried out to diode 400 like the 1st example. between the electrode 471 of diode 400, and an electrode 472, the reverse bias electrical potential difference of abbreviation 100V impresses -- having -- the anode layer 420 -- the whole region and near the pn junction side of a silicon substrate 410, it is depletion-ized mostly. An incidence acceleration electron emits kinetic energy in p mold high concentration layer 440 and the depletion-ized anode layer 420, and generates an electronic-electron hole pair. In this case, since the wideband gap layer 480 and p mold high concentration layer 440 are thin, emission of energy is hardly made but all energy is emitted substantially in a depletion region. Although the electronic-electron hole pair generated by emission of this energy is generated, on the other hand, a signal charge comes out, and just before arriving at a pn junction side, avalanche multiplication of a certain electron is carried out. In this way, the signal charge by which multiplication was carried out is outputted as a signal from an electrode 471 and an electrode 472. In addition, since an avalanche multiplication factor can usually be carried out to about 100, the very highly sensitive electron tube is realizable.

[0044] Also in the electron tube of this example, an anode layer may be formed with a diffusion wafer or a lamination wafer like the 1st example.

[0045] (The 4th example) Drawing 4 is the block diagram of the electron tube concerning this example, and drawing 4 (a) shows the configuration of the electron-beam-irradiation mold diode with which drawing 4 (b) was enclosed with the electron tube in the configuration of the whole electron tube. It is only that the electron-beam-irradiation mold diodes to enclose differ compared with the electron tube of the 1st example, and this electron tube is similarly constituted except it.

[0046] In addition to the same configuration as the electron-beam-irradiation mold diode of the 1st example, the electron-beam-irradiation mold diode 500 enclosed with the electron tube of this example forms in acceleration electronic plane of incidence the wideband gap layer 580 which has the conductivity of p mold by using as a base material the ingredient matter which has a big band gap, and consists of band gaps of silicon. Namely, this electron-beam-irradiation mold diode 500 The silicon substrate 510 of 1mm angle which has the conductivity of a (a) n mold, and n mold high concentration layer 550 formed in one front face of the (b) silicon substrate 510, p mold high concentration layer 590 formed in the predetermined field of the front face of another side of the (c) silicon substrate 510, The anode layer 520 which has the conductivity of p mold formed in the front face of another side of the (d) silicon substrate 510, The isolation layer 530 which has the conductivity of n mold formed in the field which surround anode layer 520 field of the front face of another side of the (e) silicon substrate 510, p mold high concentration layer 540 formed in the front face of the anode layer 520, (Mosquito) The silicon oxide 560 formed in the front face of the (g) isolation layer 530, and the field including near the periphery of p mold high concentration layer 540, the electrode 572 formed in the front face of the (h) n mold high concentration layer 550, the electrode 571 formed in the front face of the (i) p mold high concentration layer 540, and the wideband gap layer 580 of several nm thickness which has the conductivity of a (j) p mold -- since -- it is constituted.

[0047] The wideband gap layer 580 is constituted for the 2nd example and p mold high concentration layer 490 like the 3rd example.

[0048] If light carries out incidence to the photoelectric surface 111 of this electron tube, a

photoelectron will be generated and incidence will be carried out to diode 500 like the 1st example. between the electrode 571 of diode 500, and an electrode 572, the reverse bias electrical potential difference of abbreviation 100V impresses -- having -- the anode layer 520 -- the whole region and near the pn junction side of a silicon substrate 510, it is depletion-ized mostly. An incidence acceleration electron emits kinetic energy in p mold high concentration layer 540 and the depletion-ized anode layer 520, and generates an electronic-electron hole pair. In this case, since the wideband gap layer 580 and p mold high concentration layer 540 are thin, emission of energy is hardly made but all energy is emitted substantially in a depletion region. Although the electronic-electron hole pair generated by emission of this energy is generated, on the other hand, a signal charge comes out, a certain electron runs in the direction of a pn junction side efficiently, and avalanche multiplication is carried out just before attainment. In this way, the signal charge by which multiplication was carried out is outputted as a signal from an electrode 571 and an electrode 572.

[0049] Also in the electron tube of this example, an anode layer may be formed with a diffusion wafer or a lamination wafer like the 1st example.

[0050]

[Effect of the Invention] As mentioned above, according to the 1st electron tube of this invention, it is related with the electron-beam-irradiation mold diode to enclose as explained to the detail. Form a pn junction side in the substrate and low concentration impurity layer which contain an impurity in low concentration, and the thin high concentration impurity layer which has the same conductivity type as the low concentration impurity layer which stops growth of a depletion region is formed in the front face where the pn junction side of a low concentration impurity layer is opposite. Since it decided to cross the depletion region produced by impression of a reverse bias electrical potential difference throughout the thickness direction of a low concentration impurity layer, and to form it, it becomes possible to make a neutral zone thin, and the electron tube which improved sensibility and precision can be realized. Moreover, since the isolation diffusion layer was formed in the perimeter by the side of the side face of a low concentration impurity layer, the dark current by exposure of a pn junction side being prevented is inhibited, and improvement in the sensibility of the electron tube or precision is attained.

[0051] the configuration of the electron-beam-irradiation mold diode in the 1st electron tube above-mentioned in the 2nd electron tube concerning this invention -- in addition, since a good accumulation condition is discovered to a signal charge and a signal charge arrives at a pn junction side efficiently as a result of forming a very thin wide gap layer in the plane of incidence of an acceleration electron and carrying out a heterojunction, the electron tube which improved sensibility and precision further rather than the 1st electron tube is realizable.

[0052] In the 3rd electron tube concerning this invention, it adds to the configuration of the electron-beam-irradiation mold diode in the 1st above-mentioned electron tube. Since the high concentration impurity layer which has the same conductivity type as a low concentration impurity layer is formed between a substrate and a low concentration impurity layer, high electric field occur in this high concentration impurity layer at the time of impression of a reverse bias electrical potential difference and an avalanche multiplication function is discovered The output signal charge accompanying emission of the kinetic energy of an incidence acceleration electron increases, and the electron tube which improved sensibility and precision further rather than the 1st electron tube can be realized.

[0053] In the 4th electron tube concerning this invention, it adds to the configuration of the electron-beam-irradiation mold diode in the 2nd above-mentioned electron tube. Since the high concentration impurity layer which has the same conductivity type as a low concentration impurity layer is formed between a substrate and a low concentration impurity layer, high electric field occur in this high concentration impurity layer at the time of impression of a reverse bias electrical potential difference and an avalanche multiplication function is discovered The electron tube which has the sensibility by which the both sides of the improving point in the 2nd electron tube to the 1st electron tube and the improving point in the 3rd electron tube to the 1st electron tube have been improved, and precision is realizable.

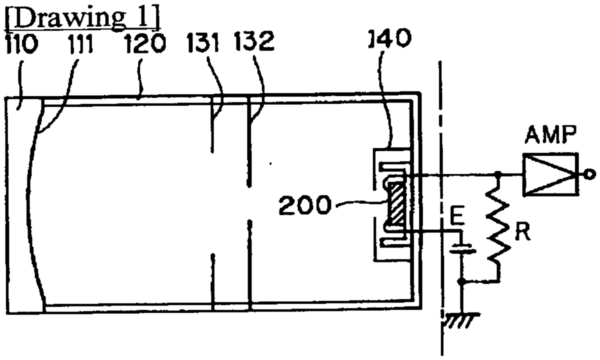
[0054] Especially when using avalanche multiplication like the 3rd and 4th photoelectric tubes, it is possible to acquire very high gain and it becomes detectable [a single photon]. Moreover, since the instability and the response characteristic of gain resulting from the dynode which becomes a

problem with the photomultiplier tube are improved, super-high sensitivity and a ultra high-speed photodetector are realizable. Furthermore, since multiplication fluctuation becomes small compared with the photomultiplier tube, an incident light child's counting also becomes possible.

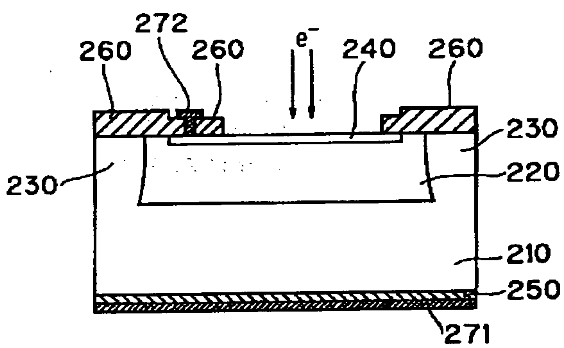
[Translation done.]

DRAWINGS

[Drawing 1]

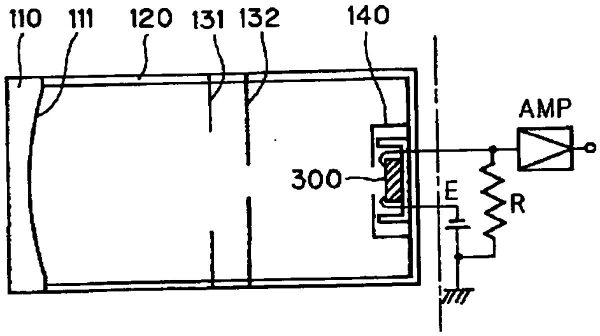


(a)第1実施例の電子管の全体構成

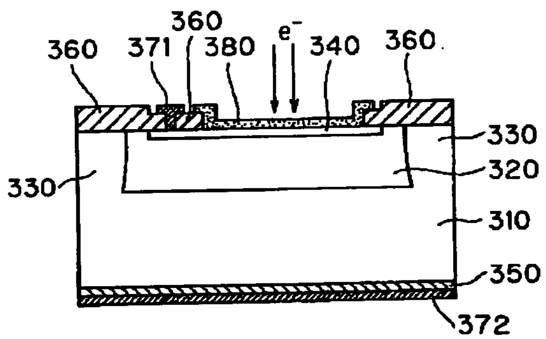


(b)電子線照射型ダイオード200の構成

[Drawing 2]

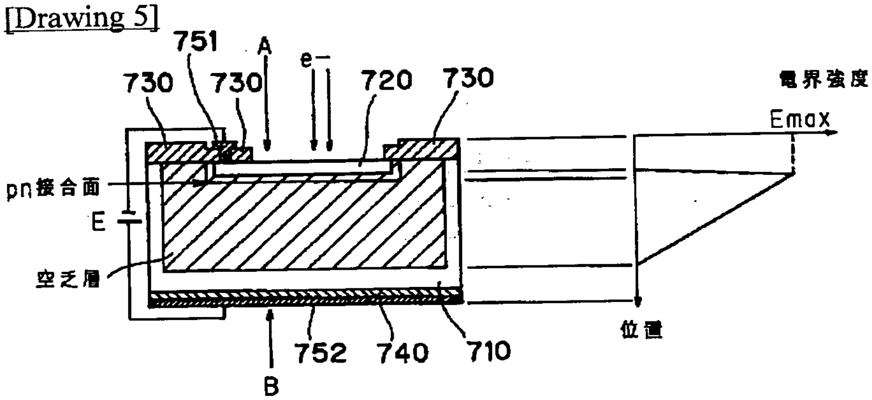


(a)第2実施例の電子管の全体構成



(b)電子線照射型ダイオード300の構成

[Drawing 5]

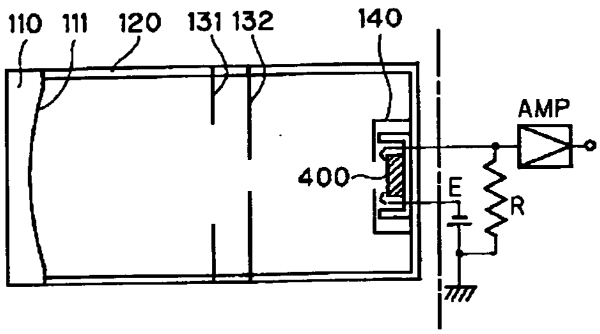


(a)

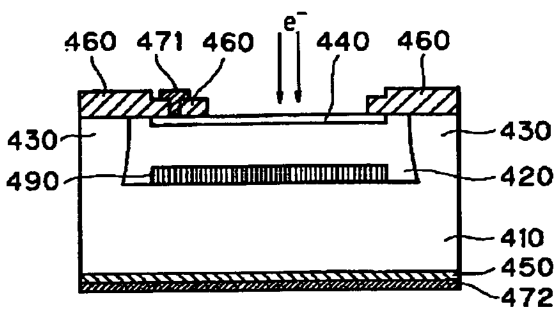
(b)

従来の電子線照射型ダイオード

[Drawing 3]

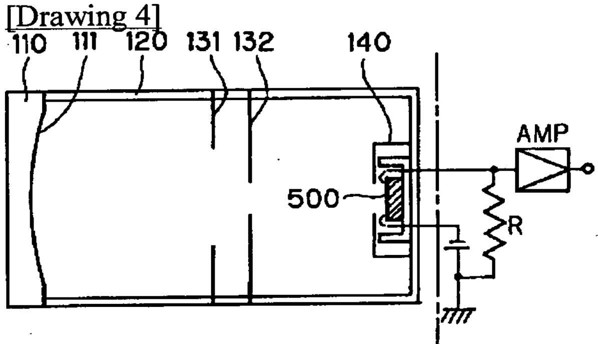


(a)第3実施例の電子管の全体構成

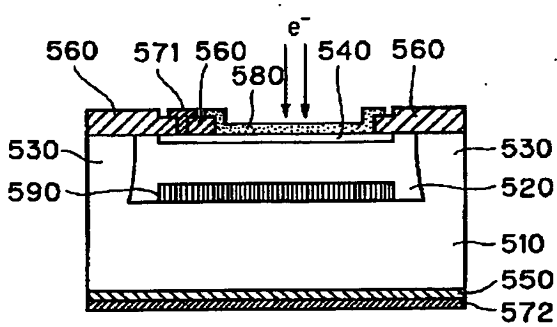


(b)電子線照射型ダイオード400の構成

[Drawing 4]



(a)第4実施例の電子管の全体構成



(b)電子線照射型ダイオード500の構成

[Translation done.]

ELECTRON TUBE

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Publication date: 1994-11-15
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Applicant: HAMAMATSU PHOTONICS KK
Classification:
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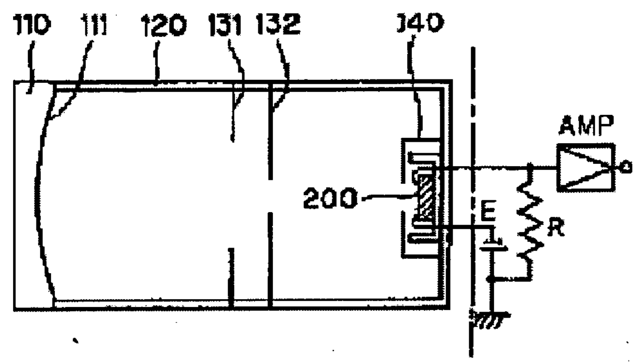
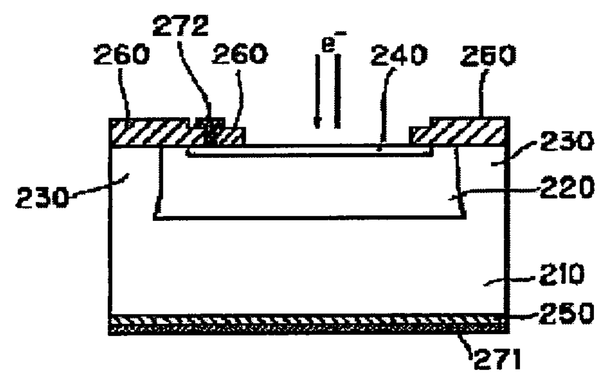
- european:
Application number: JP19930107019 19930507
Priority number(s): JP19930107019 19930507

Abstract of **JP6318447**

PURPOSE:To realize an electron beam radiation type diode having a structor in a thin dead zone which incidental electrons may not intrude into a p-n junction surface, so as to provide an electron tube having improved sensitivity and precision.
CONSTITUTION:Photoelectrons generated by light inciden to a photoelectric surface 111 are accelerated to be incident on an electron beam radiation type diode 200. An inverse bias voltage is applied between an electrode 271 and an electrode 272 of the electron beam radiation type diode 200, and almost all the range of a low concentration impurity layer 220 is formed hollow. The incidental accelerated electrons emit motion energy at a high concentration layer 240 having an electron incidental surface and the hollow low concentration impurity layer 220 to generate electron-positive hole pairs. The high concentration layer 240 having the electron incidental surface is extremely thin, so almost no energy is emitted, but substantially all the energy is emitted in the hollow range. Signal load taken from the electron-positive hole pairs generated by this emission of energy is outputted as signals. from the electrodes 271, 272.





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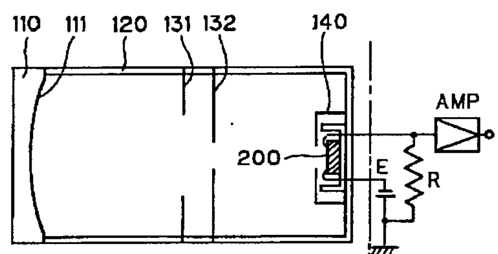
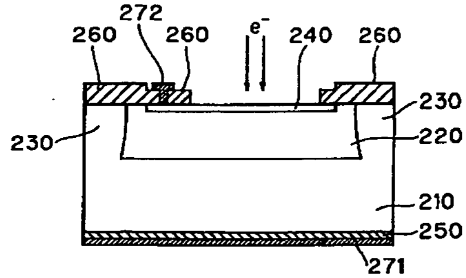
(54)【発明の名称】　電子管

(57)【要約】
【目的】　不感帯が薄く、入射電子がｐｎ接合面にまで侵入しない構造の電子線照射型ダイオードを実現し、感度と精度とを向上した電子管を提供する。
【構成】　光電面１１１に光が入射した光電子は、加速され電子線照射型ダイオード２００に入射する。電子線照射型ダイオード２００の電極２７１と電極２７２との間には逆バイアス電圧が印加され、低濃度不純物層２２０のほぼ全域は空乏化されている。入射加速電子は電子入射面を有する高濃度層２４０と空乏化された低濃度不純物層２２０とで運動エネルギを放出し、電子－正孔対を生成する。電子入射面を有する高濃度層２４０は非常に薄いので、ほとんどエネルギの放出はなされず、空乏領域で実質的に全てのエネルギを放出する。このエネルギの放出によって発生した電子－正孔対から取り出された信号電荷は、電極２７１および電極２７２から信号として出力される。



(a)第1実施例の電子管の全体構成



(b)電子線照射型ダイオード200の構成

【特許請求の範囲】

【請求項１】　半導体電子線検出器を封入した電子管であって、
前記半導体電子線検出器は、
第１の導電型を有するシリコン基板と、
前記シリコン基板の一方の表面に形成された第１の導電型を有する第１の高濃度不純物層と、
前記シリコン基板の他方の表面に形成された第２の導電型を有する低濃度不純物層と、
前記シリコン基板の前記他方の表面の前記低濃度不純物層領域を取り巻く領域に形成された第１の導電型を有するアイソレーション層と、
前記低濃度不純物層の表面に形成された第２の導電型を有する第２の高濃度不純物層と、
前記アイソレーション層の表面と前記第２の高濃度層の表面の外周付近を含む領域に形成されたシリコン酸化膜と、
前記第１の高濃度不純物層の表面に形成された第１の電極と、
前記第２の高濃度不純物層の表面に形成された第２の電極と、
から構成され、前記第２の高濃度不純物層の表面から電子を入射することを特徴とする電子管。

【請求項２】　半導体電子線検出器を封入した電子管であって、
前記半導体電子線検出器は、
第１の導電型を有するシリコン基板と、
前記シリコン基板の一方の表面に形成された第１の導電型を有する第１の高濃度不純物層と、
前記シリコン基板の他方の表面に形成された第２の導電型を有する低濃度不純物層と、
前記シリコン基板の前記他方の表面の前記低濃度不純物層領域を取り巻く領域に形成された第１の導電型を有するアイソレーション層と、
前記低濃度不純物層の表面に形成された第２の導電型を有する第２の高濃度不純物層と、
前記アイソレーション層の表面と前記第２の高濃度不純物層の表面の外周付近を含む領域に形成されたシリコン酸化膜と、
前記第１の高濃度不純物層の表面に形成された第１の電極と、
前記第２の高濃度不純物層の表面に形成された第２の電極と、
前記第２の高濃度不純物層の表面の前記シリコン酸化膜が形成された領域と前記第２の電極が形成された領域とを除く領域に形成された、前記第２の高濃度不純物層の有するバンドギャップよりも大きなバンドギャップを有し、第２の導電型を有する半導体材料からなり、前記第２の高濃度不純物層とヘテロ接合するワイドバンドギャップ層と、
から構成され、前記ワイドバンドギャップ層の表面から電子を入射することを特徴とする電子管。

【請求項３】　半導体電子線検出器を封入した電子管であって、
前記半導体電子線検出器は、
第１の導電型を有するシリコン基板と、
前記シリコン基板の一方の表面に形成された第１の導電型を有する第１の高濃度不純物層と、
前記シリコン基板の他方の表面の第１の領域に形成された第２の導電型を有する第２の高濃度不純物層と、
前記シリコン基板の前記他方の表面の前記第１の領域を囲む第２の領域と前記第２の高濃度不純物層の表面に形成された第２の導電型を有する低濃度不純物層と、
前記シリコン基板の前記他方の表面の前記低濃度不純物層領域を取り巻く領域に形成された第１の導電型を有するアイソレーション層と、
前記低濃度不純物層の表面に形成された第２の導電型を有する第３の高濃度不純物層と、
前記アイソレーション層の表面と前記第３の高濃度層の表面の外周付近を含む領域に形成されたシリコン酸化膜と、
前記第１の高濃度不純物層の表面に形成された第１の電極と、
前記第３の高濃度不純物層の表面に形成された第２の電極と、
から構成され、前記第３の高濃度不純物層の表面から電子を入射することを特徴とする電子管。

【請求項４】　半導体電子線検出器を封入した電子管であって、
前記半導体電子線検出器は、
第１の導電型を有するシリコン基板と、
前記シリコン基板の一方の表面に形成された第１の導電型を有する第１の高濃度不純物層と、
前記シリコン基板の他方の表面の第１の領域に形成された第２の導電型を有する第２の高濃度不純物層と、
前記シリコン基板の前記他方の表面の前記第１の領域を囲む第２の領域と前記第２の高濃度不純物層の表面に形成された第２の導電型を有する低濃度不純物層と、
前記シリコン基板の前記他方の表面の前記低濃度不純物層領域を取り巻く領域に形成された第１の導電型を有するアイソレーション層と、
前記低濃度不純物層の表面に形成された第２の導電型を有する第３の高濃度不純物層と、
前記アイソレーション層の表面と前記第３の高濃度不純物層の表面の外周付近を含む領域に形成されたシリコン酸化膜と、
前記第１の高濃度不純物層の表面に形成された第１の電極と、
前記第３の高濃度不純物層の表面に形成された第２の電極と、

前記第３の高濃度不純物層の表面の前記シリコン酸化膜が形成された領域と前記第２の電極が形成された領域とを除く領域に形成された、前記第３の高濃度不純物層の有するバンドギャップよりも大きなバンドギャップを有し、第２の導電型を有する半導体材料からなり、前記第３の高濃度不純物層とヘテロ接合するワイドバンドギャップ層と、

から構成され、前記ワイドバンドギャップ層の表面から電子を入射することを特徴とする電子管。

【発明の詳細な説明】

【０００１】

【産業上の利用分野】本発明は、入射した光を検出する光電管に係わり、特にアノードとして電子線照射型ダイオードを使用する光電管に関するものである。

【０００２】

【従来の技術】シリコン素子に電子が入射すると、電子は運動エネルギを放出し、最終的には静止する。シリコン素子の中では、放出されたエネルギ３．６ｅＶごとに１対の電子－正孔が生成する。したがって、－１０ｋＶが印加された光電面から放出された電子がシリコン素子に入射すれば、約２８００個の電子－正孔対が生成され、対の一方を信号電荷として取り出すことが可能である。したがって、光電面を有する電子管にアノードとして、シリコンダイオードを封入すという構成で、非常に高感度であり、且つ入射した光子数を定量的に計測できる光検出器を構成することが原理的には可能であり、製品開発が進められている。

【０００３】図５は、上記の原理を応用した従来の電子管でアノードとして使用される半導体電子検出器としての電子線照射型ダイオードの構成図である。図５（ａ）はこの電子線照射型ダイオードの構造断面を示し、図５（ｂ）はこの半導体電子検出器の電極管に電圧を印加した場合の内部における電界強度の分布を示す。この電子線照射型ダイオードは、（ａ）２００μｍ厚、１ｋΩ－ｃｍの抵抗を有する高抵抗ｎ型シリコン基板７１０と、（ｂ）基板７１０といわゆる階段接合し、５×１０^{19}ｃｍ$^{-3}$のｐ型不純物を含む、深さが０．５μｍのｐ型高濃度拡散層７２０と、（ｃ）ｐ型高濃度拡散層７２０の電子線の入射領域を除いた表面領域と基板７１０のｐ型高濃度拡散層７２０を形成した側の表面とに形成されたシリコン酸化膜７３０と、（ｄ）基板７１０のｐ型高濃度拡散層７２０を形成した側と反対側の表面に形成され、逆バイアス電圧の印加時の基板７１０内の空乏層広がりを停止させるｎ型高濃度層７４０と、（ｅ）ｐ型高濃度拡散層７２０の電子線の入射領域を除いた表面領域に形成された電極７５１と、（ｆ）ｎ型高濃度層７４０の表面に形成された電極７５２と、から構成される。

【０００４】ここで、ｐ型高濃度拡散層７２０の電子線の入射領域にシリコン酸化膜を形成しない理由は、シリコン酸化膜が不感帯となり、その中で吸収された入射電

子の運動エネルギによって生じる電子－正孔対として発生した電荷を信号電荷として取り出すことができないためである。

【０００５】また、基板７１０として高抵抗（１ｋΩ－ｃｍ）のシリコン部材を使用する理由は、逆バイアス電圧を印加して空乏層を広げるとともに、接合容量を小さくして高速性を達成するためである。例えば、上記の電子線照射型ダイオードに１５０Ｖの逆バイアス電圧を印加して基板７１０の厚み全体に関して空乏状態とした場合には、接合容量が約０．５ｐＦとなる。外付けの負荷抵抗は通常５０Ωであるから、ＣＲ時定数は２５ｐｓｅｃとなり、電子管に封入される電子検出器として要求されるナノ秒オーダの動作が可能である。なお、シリコン酸化膜７３０は暗電流の抑制のために形成されている。

【０００６】図５（ｂ）は、以上の電子線照射型ダイオードに逆バイアス電圧を印加した場合の図５（ａ）におけるＡ－Ｂ間での電界強度分布を示す。図示の通り、空乏層内では信号電荷（電子）を移動させる電界が発生しており、ｐｎ接合面で極大値となる様子を示している。

【０００７】電子管の光電面に光が入射すると、光電面から電子が放出される。この電子は光電面とアノードである上記の電子線照射型ダイオードとの間に印加された電圧によって加速され、遮光板によって選択された電子が電子線照射型ダイオードにｐ型高濃度拡散層７２０の電子線入射面から入射する。入射した電子は、電子線照射型ダイオードを構成するシリコン部材中で運動エネルギを放出し、電子－正孔対を生成する。この時、電子線照射型ダイオードには逆バイアス電圧が印加され、基板７１０は空乏化している。空乏層で電子－正孔対として発生した信号電荷は、信号電流として出力される。

【０００８】

【発明が解決しようとする課題】従来の電子管で使用されている電子線照射型ダイオードは上記のように構成され、電子線が入射する高濃度不純物層は導電性が良い。これは、逆バイアス電圧を印加した場合、この高濃度不純物層にも空乏領域が成長するが、空乏領域がシリコン酸化膜との界面にまで至ると、いわゆる表面準位のため暗電流が大幅に増加するので、これを防止するためである。したがって、高濃度不純物層での空乏領域はｐｎ接合面の近傍の非常に薄い領域にしか形成されないので、電子線の入射面から空乏層までの領域である高濃度不純物層のほとんどの領域は不感帯となる。この不感帯で発生した電子－正孔対から信号電荷を有効に取り出すことはできないので、光検出器としての電子管の感度や精度を低下させるので、高濃度不純物層は薄いほど好ましい。

【０００９】しかし、高濃度不純物層を薄くすればするほど電界集中が大きくなり、降伏電圧が小さくなる。更に、高濃度不純物層の厚さに対する接合の湾曲の度合いが大きくなると降伏電圧は極端に小さくなる。すなわ

ち、高速動作のために高抵抗を有する基板に十分な空乏領域を形成する逆バイアス電圧の印加を確保するには、ある程度の厚みを有する高濃度不純物層が必須であり、光検出器としての電子管の感度や精度の低下が避けられない、という問題があった。

【００１０】また、光電面で発生した電子は加速されて電子線照射型ダイオードに入射するので、運動エネルギを放出して静止するまでにｐｎ接合面を通過することがある。例えば、上記のように１０ｋｅＶに加速された電子がシリコンに入射すると、入射面から平均で数μｍ程度侵入するので、０．５μｍの高濃度不純物層の厚さではほぼ確実に電界強度の最も大きいｐｎ接合面を通過する（図５（ｂ）参照）。高エネルギ電子の通過によりシリコンのバンドギャップ中に多数のエネルギレベルが作り出される（S.M.SZE : Physics of Semiconductor Devives, p.49）。これらのエネルギレベルは暗電流の原因となるが、電界強度の大きなｐｎ接合面付近でのバンドギャップ中における多数のエネルギレベルの生成は大きな暗電流の原因となり、電子管としての感度や精度に対して悪影響を与えるという問題点があった。

【００１１】更に、電子の照射が進めばｐｎ接合面が荒れてしまうことにより、逆バイアス電圧に対する耐圧の低下が想定される。耐圧が低下すると、基板に広く空乏層を広げるほどには逆バイアス電圧を印加することができず、ＣＲ時定数が大きくなり動作速度が低下するという問題点があった。

【００１２】本発明は、上記の状況を鑑みてなされたものであり、不感帯を薄くでき且つ入射電子がｐｎ接合面にまで侵入しない構造の電子線照射型ダイオードを実現することにより、感度および精度を向上した電子管を提供することを目的とする。

【００１３】

【課題を解決するための手段】本発明の電子管は、封入する半導体電子検出器である電子照射型ダイオードのｐｎ接合面を不純物を低濃度に含む基板と低濃度不純物層である低濃度不純物層とで形成する。逆バイアス電圧の印加によって生じる空乏領域を基板と低濃度不純物層との厚さ方向の全域に渡って形成するとともに、低濃度不純物層のｐｎ接合面とは反対の表面に空乏領域の成長を止める低濃度不純物層と同一の導電型を有する高濃度不純物層を形成する。この結果、この高濃度不純物層の厚さは耐圧の要因とならず、この高濃度不純物層の厚さを薄くすることができる、ことを利用して従来の電子管の問題点の解決を図っている。

【００１４】すなわち、本発明の第１の電子管は、半導体電子線検出器を封入した電子管であって、半導体電子線検出器は、（ａ）第１の導電型を有するシリコン基板と、（ｂ）シリコン基板の一方の表面に形成された第１の導電型を有する第１の高濃度不純物層と、（ｃ）シリコン基板の他方の表面に形成された第２の導電型を有する低濃度不純物層と、（ｄ）シリコン基板の他方の表面の低濃度不純物層領域を取り巻く領域に形成された第１の導電型を有するアイソレーション層と、（ｅ）低濃度不純物層の表面に形成された第２の導電型を有する第２の高濃度不純物層と、（ｆ）アイソレーション層の表面と第２の高濃度層の表面の外周付近を含む領域とに形成されたシリコン酸化膜と、（ｇ）第１の高濃度不純物層の表面に形成された第１の電極と、（ｈ）第２の高濃度不純物層の表面に形成された第２の電極と、から構成され第２の高濃度不純物層のシリコン酸化膜が形成されていない表面から電子を入射することを特徴とする。

【００１５】本発明の第２の電子管は、半導体電子線検出器を封入した電子管であって、半導体電子線検出器は、上記第１の電子管における半導体電子線検出器の第２の高濃度不純物層の表面の前記シリコン酸化膜が形成された領域と第２の電極が形成された領域とを除く領域とに、第２の高濃度不純物層の有するバンドギャップよりも大きなバンドギャップを有する半導体材料からなり、前記第２の高濃度不純物層とヘテロ接合するワイドバンドギャップ層が形成され、ワイドバンドギャップ層の表面から電子を入射することを特徴とする。

【００１６】本発明の第３の電子管は、半導体電子線検出器を封入した電子管であって、半導体電子線検出器は、上記第１の電子管における半導体電子線検出器の基板と低濃度不純物層との間に高濃度不純物層を形成した、ことを特徴とする。

【００１７】本発明の第４の電子管は、半導体電子線検出器を封入した電子管であって、半導体電子線検出器は、上記第２の電子管における半導体電子線検出器の基板と低濃度不純物層との間に高濃度不純物層を形成した、ことを特徴とする。

【００１８】

【作用】本発明に係る第１の電子管では、電子線照射型ダイオードには逆バイアス電圧が印加されており、低濃度不純物層の厚さ方向の全領域は空乏化している。したがって、加速電子の電子線照射型ダイオード内における侵入領域で空乏化していないのは、低濃度不純物層の表面に形成された低濃度不純物層と同一の導電型を有する高濃度不純物層のみである。また、アイソレーション拡散層は、ｐｎ接合面が側面に露出することを防止するので、暗電流を抑止する。

【００１９】この電子管の光電面に光が入射すると光電子を発生する。この光電子は加速され電子線照射型ダイオードに入射する。この入射加速電子は電子入射面を有する高濃度不純物層と空乏化された低濃度不純物層あるいは基板とで運動エネルギを放出し、電子－正孔対を生成する。この場合、電子入射面を有する高濃度不純物層は非常に薄いので、ほとんどエネルギの放出はなされず、空乏領域で実質的に全てのエネルギを放出する。このエネルギの放出によって発生した電子－正孔対から取

り出された信号電荷は、電極から信号として出力される。

【0020】本発明に係る第2の電子管では、上記の第1の電子管における電子線照射型ダイオードの構成に加えて、非常に薄いワイドギャップ層が加速電子の入射面に形成されヘテロ接合する結果、信号電荷に対して良好なアキュムレーション状態が発現する。この状態で、この電子管の光電面に光が入射するのにともなって発生した光電子を加速して電子線照射型ダイオードに入射すると、第1の電子管と同様に電子－正孔対を生成するが、加速電子の入射面付近が良好なアキュムレーション状態となっているので、信号電荷の一方が効率良くｐｎ接合面に到達し、信号電荷の他方との表面付近での再結合を低減できる。こうして効率良く収集した信号電荷は、電極から信号として出力される。なお、ワイドバンドギャップ層は一種のパッシベーション膜としても作用し、封入時に発生するアルカリ金属の汚染から電子線照射型ダイオードを保護する。

【0021】本発明に係る第3の電子管では、上記の第1の電子管における電子線照射型ダイオードの構成に加えて、基板と低濃度不純物層との間に低濃度不純物層と同一の導電型を有する高濃度不純物層を形成されており、逆バイアス電圧の印加時にはこの高濃度不純物層に高電界が発生しアバランシェ増倍機能が発現する。この状態で、この電子管の光電面に光が入射にともなって発生した光電子を加速して電子線照射型ダイオードに入射すると、第1の電子管と同様に電子－正孔対が生成され、信号電荷の一方はｐｎ接合面への方向に進行する。この信号電荷の一方は、ｐｎ接合面を通過する直前にアバランシェ増倍される。したがって、基板に到達する信号電荷の総量は第1の電子管の場合に比べて増大したものとなる。こうして増大した信号電荷は、電極から信号として出力される。

【0022】本発明に係る第4の電子管では、上記の第2の電子管における電子線照射型ダイオードの構成に加えて、基板と低濃度不純物層との間に低濃度不純物層と同一の導電型を有する高濃度不純物層を形成されており、逆バイアス電圧の印加時にはこの高濃度不純物層に高電界が発生しアバランシェ増倍機能が発現する。したがって、第1の電子管に対しての第2の電子管における改善点および第1の電子管に対しての第3の電子管における改善点の双方が改善された作用を有する。この結果、効率良くｐｎ接合面への方向へ進行する信号電荷がアバランシェ増倍されて、電極から信号として出力される。

【0023】

【実施例】以下、添付図面を参照して本発明の実施例を説明する。なお、図面の説明において同一の要素には同一の符号を付し、重複する説明を省略する。

【0024】（第1実施例）図1は本実施例に係る電子管の構成図であり、図1（ａ）は電子管全体の構成を、図1（ｂ）は電子管に封入された電子線照射型ダイオードの構成を示す。この電子管は、光を受光して電子を放出する光電面１１１を有する光電面板１１０と、ガラスバルブ１２０とで封入容器を構成し、封入容器内に、光電面から放出された電子を絞り込む第1グリッド１３１および第2グリッド１３２と、加速された電子の進路を制限する遮蔽板１４０と、入射した加速電子を検出して信号電荷を出力する電子線照射型ダイオード（以後、単にダイオードとも称する）２００と、を含んで構成される。ダイオード２００には、直流電源（Ｅ）から負荷抵抗（Ｒ）を介して逆バイアス電圧が印加される。ダイオード２００で発生した信号電荷が負荷抵抗（Ｒ）を流れることによって生じた負荷抵抗（Ｒ）の両端に発生した電圧信号は増幅器（ＡＭＰ）に入力される。なお、本実施例の電子管では光電子の加速電圧は１０ｋＶであり、したがって、加速電子のシリコン部材への侵入深さは数μｍである。

【0025】ダイオード２００は、（ア）ｎ型の導電性を有する１ｍｍ角のシリコン基板２１０と、（イ）シリコン基板２１０の一方の表面に形成されたｎ型の導電性を有する高濃度不純物層（以後、ｎ型高濃度層と称する）２５０と、（ウ）シリコン基板２１０の他方の表面に形成されたｐ型の導電性を有するアノード層２２０と、（エ）シリコン基板２１０の他方の表面のアノード層２２０領域を取り巻く領域に形成されたｎ型の導電性を有するアイソレーション層２３０と、（オ）アノード層２２０の表面に形成されたｐ型の導電性を有する高濃度不純物層（以後、ｐ型高濃度層と称する）２４０と、（カ）アイソレーション層２３０の表面とｐ型高濃度層２４０の外周付近を含む領域とに形成されたシリコン酸化膜２６０と、（キ）ｎ型高濃度層２５０の表面に形成された電極２７１と、（ク）ｐ型高濃度層２４０の表面に形成された電極２７２と、から構成される。

【0026】本実施例では、シリコン基板２１０は、比抵抗０．０１Ωｃｍとなる程度のｎ型不純物を含有する２００μｍ厚のシリコンから形成され、アノード層２２０は、比抵抗が１００Ωｃｍ程度となるｐ型不純物を含有するシリコンをエピタキシャル成長で４０μｍ厚に形成する。

【0027】また、アイソレーション拡散層２３０は、ｎ型シリコン基板２１０の一方の表面にｐ型層を形成後、ｐ型層（結果的にはシリコン基板の一部を含んで）の所定の領域にｎ型不純物を拡散して形成され、ｐｎ接合面が側面に露出することを防止する。この結果、暗電流を抑止する。

【0028】また、ｐ型高濃度層２４０は5×10^{19}ｃm^{-3}の不純物濃度を有する０．１μｍ厚の層である。この厚さのほぼ全てが不感帯となるが、従来の電子照射型ダイオードの構成に比べて不感帯の厚さが低減される。